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CAD/CAM for the Fabrication of Steel Structures

CAO/CAM pour la fabrication de charpentes métalliques

CAD/CAM für die Herstellung von Stahlbauteilen

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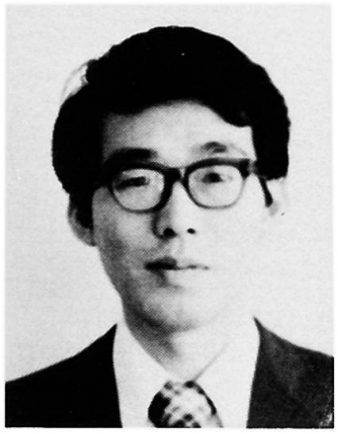

SUMMARY
This paper presents an outline of the whole system with the basic concept. This system will be in promoting the systematization in the industry of multi kind and small quantity production type. The main function of this system are automated drafting and manufacturing.

RESUME
Cet article trace les grandes lignes du système entier, en montrant le concept de base. Ce système permet la production systématique et industrielle de nombreux produits en petites quantités. Les principales fonctions de ce système sont le dessin et la fabrication automatisés.

ZUSAMMENFASSUNG
Der Beitrag gibt einen Überblick über das ganze System mit dem zu Grunde liegenden Konzept. Das System wird die Systematisierung in Industrien mit kleinen Stückzahlen und Modellvielfalt unterstützen. Die Hauptfunktionen des Systems sind das automatische Zeichnen und die automatische Fabrikation.

1. INTRODUCTION

Steel structures are to be produced on orders. With change of the times, their production has been more diversified and complicated in process and larger in scale. The structural steel fabricating industry is now strongly required to improve the productivity while meeting such social conditions.

Our company has been making efforts to develop an automated production system using digital computer and NC machine for bridges and steel structures. Such system is already in actual operation in the Bridge Division. In the Steel Structure Division, however, development of such system was found far more difficult than expected. We have not yet formed a clear view also about the effect and availability of such system at the stage of application.

Meanwhile, basic conditions for the development of such system have been gradually established by introduction of hardwares such as large capacity computer and NC machines, development of basic softwares such as languages and data bases for graphic data processing and introduction of on-line system. At the same time, investigations were also made on the shop drawings for automatic drawing. As the result, it was decided to adopt the form capable of corresponding also to the flow of manufacturing particularly through simplification of expression method and classification of drawing system by functions.

Then, with these circumstances for a back ground, we intended to establish the more advanced production system by promoting the systematization from a new point of view.

This report presents an outline of the whole system with the basic concept of such system brought into focus.

2. OUTLINE OF SYSTEM

2.1 General

As for the automation of steel structure production, partial systematization in which drawing and manufacturing processes will be individually handled can hardly be expected to produce any effect. For this reason, it is necessary to realize a total system covering all kinds of information concerning the steel structure production such as preparation of shop drawings, documents on materials and various data for fabrication, full scale drawings, and operation tapes and documents for NC machines. The key concept of this total system is information control. Therefore, all items of information in the system must be under concentrated and reasonable control without overlapping and be always ready for change, alteration, modification and addition. The present system developed on the basis of this concept makes it possible to realize labor-saving, reduction of construction term and improvement of product quality by securing clear and smooth transmission of information including the unified application of information.

In addition to the above-mentioned points, systematization should be made with due regard to processing of graphic information, flexible application and control of vast volume of data and labor-saving of input data. To solve these problems, we have positively proceeded with the development of languages for graphic data processing, introduction of data bases into system and consolidation of on-line system, aiming at the higher efficiency of development.

With the above-mentioned facts kept in mind, systems configuration together with the organization for systems application and information control will be described hereinbelow.

3. DETAILS OF SYSTEM

3.1 Systems configuration

The whole system can be largely divided intc external sub-systems and internal ones. The external sub-systems mean the information control and factory manufacturing, the organizations for transmitting any information to internal and external organizations through the system. The information control serves to perform activities such as prearrangements with external organization (client), preparation of input data, preparation of changed data, checking of output results, and transmission of information to each work unit in the factory manufacturing. This is therefore regarded as a kind of information center and is involved also in integration of conventional operations. The factory manufacturing means the production line which receives any production information and performs fabrication and manufacturing based on such information. In this line are now installed NC machines as particularly direct labor-saving machines including the layout machine, cutting machine and drilling machine, this making it easier to shift to the automated production line in future. In contrast to this, the internal sub-systems consist of hardwares and softwares mainly for information processing by computer. The configuration of internal sub-systems is shown in more detail in Fig. 1.

In the following, mention will be made of the relation between structural elements of information processsing system such as input data, data base registration programs, file organization and processing programs with the data bases taken as main subject to explain our way of thinking about the steel structures.

3.2 Input data

(1) Input data for drawing

These data consist of a kind of general common items (general data), those for definition of framed construction of steel structures (structural data), those for giving the characteristics parameters of each steel member (member data), and those for standardization of bolt joints, sectional shape, etc. (standard data), all of which are to be handled at a drawing level.

(2) Inputs for materials

These inputs are classified by the contents and accuracy of data into those for estimation, those for arrangement for materials and those for material list to be used at the time of manufacturing.

(3) Inputs for fabrication

These inputs contain the data to be added to the information at the level of drawing in consideration of the conditions at the time of fabrication. These data consist of cutting allowances at the time of cutting, drilling data on the relation between bolt diameter and bolt hole at the time of drilling, welding data on shrinkage at the time of welding, and assembling allowance.

(4) Conversational inputs

These inputs are to make alterations and/or modifications to the registered data. On the assumption that an on-line terminal device or graphic display may be used to input these data, the information controller can intervene freely in the data. These inputs contain all of the above-mentioned items. As for the graphic information, these inputs serve as a means for expressing the graphic data on the graphic display and registering them after modification.

3.3 Data base registration program

(1) General file

This file can freely register simple numerical values or data necessary for

steel member manufacturing operations after the predetermined variable code name has been allotted to each of them according to the contents of general data.

(2) Structure (skelton) file registration

The lines to be taken as a basic line for framing in the steel structure and the lines on which members are actually arranged (member lines) are registered as geometrical data on the three-dimensional coordinates. Basically, they are expressed by the use of the concept of "plane, line and point" and correlation between plane, line and point. The registration program serves to perform automatic generation of data through the utilization of part program for each kind of structure made up in consideration of the characteristic features of building construction and register such data in the data base.

(3) Member file registration

This is to register the characteristics of member picked up one by one from the drawing. In this sense, the data tend to be larger in volume, thus leading to the very low efficiency of operation. For this reason, functions for automatic generation of members (manufacturing and treatment of members) and members are systematized and classified by the relation between members. And, using the conversational programs prepared according to such classification, it is intended to improve the efficiency of operation.

(4) Standard file registration

The standard data such as hole patterns of bolt joints, sectional shapes of members to be used, graphics to be used in great number at the time of fabrication and on the drawings, and mutually fixed condition of members are registered.

3.4

(1) General file

This file handles comparatively simple data such as a kind of general common items in drawing and production, previous steps to be taken in the applicable job, and control data in batch processing. The data contain:

- Title of job, job No., name of owner, place of construction, date
- Basic beam arrangement in each floor, basic data on bolt hole, basic sectional size for each kind of member
- Relation between the whole structure and orientation, direction to be followed at the time of erection
- Table of design mark and section code relating to the section of member, table of design mark and joint mark

By rational application of data in the general file, the system can show its effect of significantly reducing the inputting operation concerning the structure and members.

(2) Standard file

This file handles the bolt joint standards, member section standards, members installation standards and shape standards. Basically, the data are divided into those to be applied to all jobs and those to be applied only to the specific job. This file consists of:

- Splice file: Bolt hole patterns of bolt joints are stored as simple data for pitch and gauge with a hole pattern mark allotted to each of them. It is also possible to make a master hole pattern by combination of these basis patterns. This file is so designed that it may handle even more complicated patterns.
- Steel section file and variable section file: The steel section file handles basic sectional shapes. The variable section file has combinations and changed positions of steel section file on the member axis. This means that, no matter how significant sectional change any one member may show, its section can be expressed by marks on the variable section file.
- Fitting file: This file has an information on mutual fitting of members,

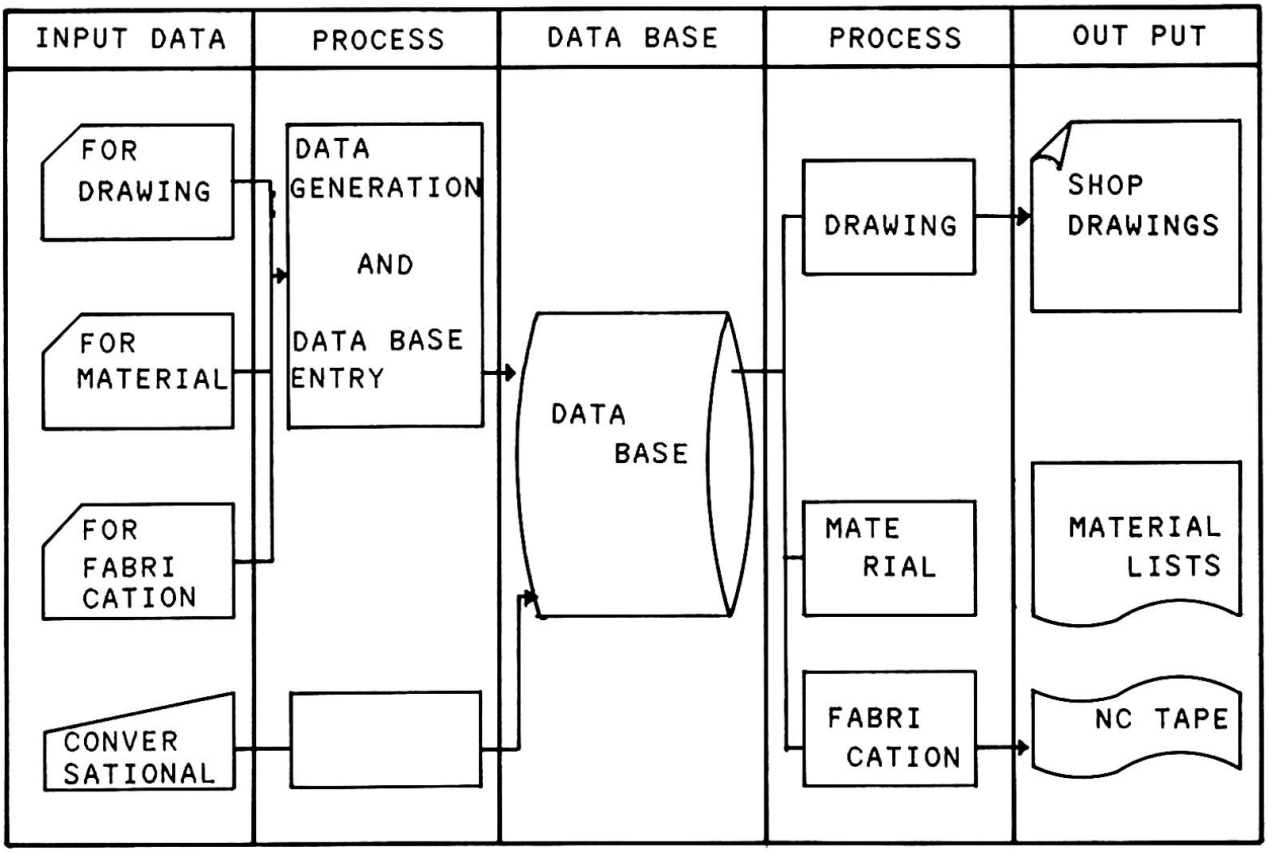

FIG .1 INTEGRATE-SYSTEM

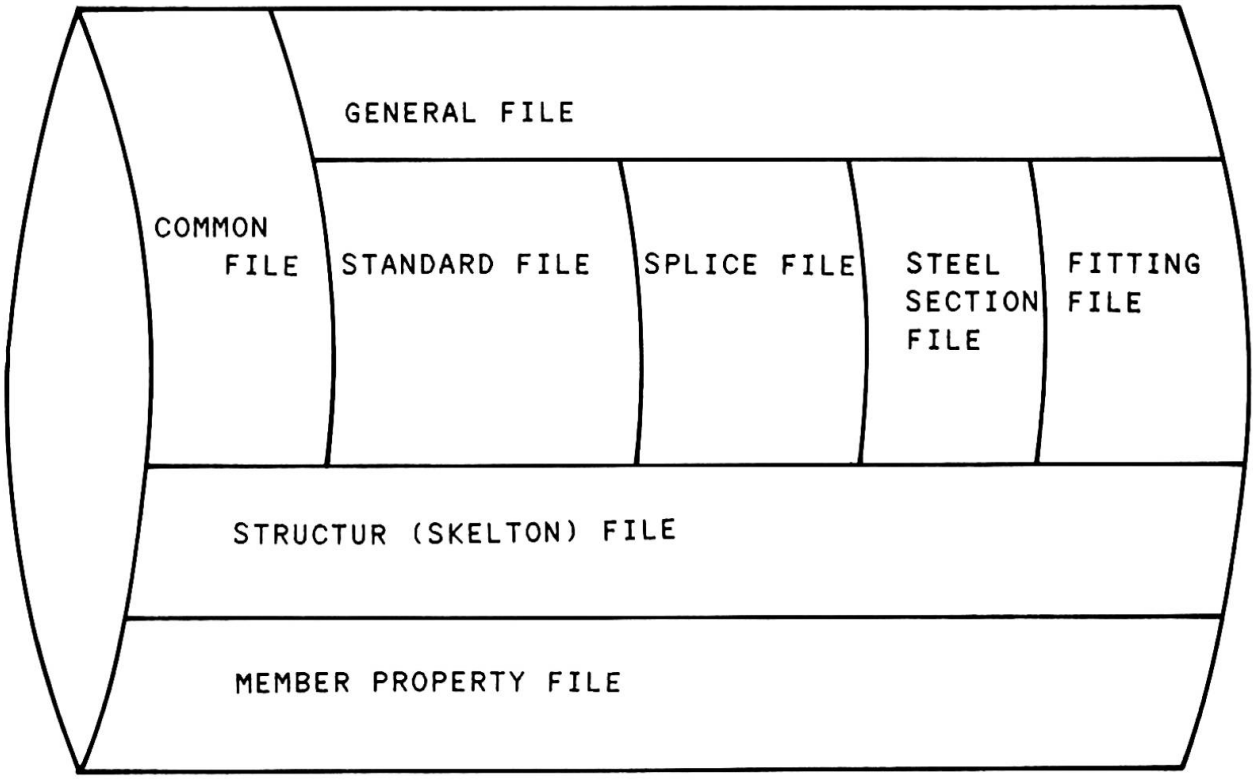

FIG .2 DATA BASE

consisting of fitting marks and fitting positions and fitting angles represented by three-dimensional coordinate values.

(3) Member (property) file

The member file serves to express the characteristics of members constituting the steel structure and handle the relation between the standard file and structure file. This file has a function as a master file in automatic drawing processing and is featured in that it contains all necessary data for automatic drawing as parameters.

Now, mention is made of systematic classification of steel structural members made by our company according to their respective characteristic features.

Classification of members by composition:
- Block members ... Unit member as product or for dispatch
- Sub-block members ... Unit member as intermediate product. These members are line members to be handled as calculation elements in structural design and are corresponding in this unit to the structure file.
- Single piece members ... The minimum unit member for fabrication

This classification corresponds also to the file organization in the member file and the system of shop drawings.

Classification of single piece members by purposes of use:
- Main piece members ... Of single piece members constituting the sub-block member, those pieces constituting its main line member
- Joint piece members ... Pieces constituting the joint in the block or sub-block members (for example, gussets, splices, fillers, etc.)
- Stiffening piece members ... Pieces for stiffening in structural design (for example, stiffeners, diaphragms, etc.)
- Equipment piece members ... Pieces for building equipment (for example, sleeves, fasteners, etc.)
- Erection piece members ... Pieces necessary for site erection (for example, hangers, ladders, etc.)
- Others

This classification of single piece members relates to member preparation processing. Therefore, if the parameters such as fitting positions, shapes of members are set up for each of such classifications, the efficiency of processing may be improved. These files form a hierchical structure in the order of block, sub-block and piece. Each file can thus call its constituent members automatically. It is therefore possible to express comparatively simply the mutual relationship between members, one of problematic points in the steel structures. The member file has all items of information at the drawing level and serves to prepare the master file by using parameters for member preparation for the purpose of member processing.

(4) Structure (skelton) file

The structure file serves to set up the framework of the whole steel structure on the three-dimensional coordinate system and handle the relation between the members constituting the framework and basic lines, mutual relationship between members, and coordinate values on the three-dimensional coordinate system. In this file, all members to be handled are such members as may be expressed as line members and these are represented by lines. Those members expressed as line members correspond to the sub-block members in the member file. The relation between the members and general structure is represented by planes and lines while mutual relationship between members is represented by lines and points. Accordingly, in the structure file, all data are expressed by the concept of "plane, line and point" which is, in turn, expressed like a network.

The structure file in the data base is composed of:
- Plane file ... Corresponds to the plan (framing plane) and elevation (framing

elevation) in the general drawing.
- Line group file ... Represents the group of reference lines such as lines of alignment and column reference lines.
- Line file ... Represents all items to be expressed lines such as reference lines and member lines.
- Point file ... Represents the intersections of lines, joint points of members, etc. The coordinate values are stored herein.

The structure file handles the relevant data in the basic framework only and has an information of such degree as may show the mutual relation between members. The more detailed values are to be given as correction values in the member file.

(5) Master file

While the design and production have conventionally been connected with each other through the graphic information, the master file plays the role of intermediate medium in this system. The master file is divided according to the contents of data itself into two parts, though these two parts are all the same in internal specification. One is for members of the same size and shape as those expressed in the shop drawing and is called the "Pre-master File." The other is the file same as this pre-master file except that fabrication data are added to it and is called the "Master File."

The master file is composed of:
- Head file ... Title of job, job No., date of preparation, etc.
- Inherent file ... Shape of single piece, hole information, fitting information, etc.
- Block file ... The relation of block with single pieces constituting it.

The master file consists mainly of inherent file in which the shape of single piece is expressed by structural lines. This file has all items of information necessary for fabrication of single pieces such as material, plate thickness, hole information and marking information. This file is therefore playing a leading role in the subsequent production processing and serves as a source of information for production.

3.5 Processing program

(1) Drawing processing program

The drawing processing program serves to perform automatic preparation of shop drawings using the data other than those stored in the master file. Somewhat unlike the conventional drawing system, the shop drawing is divided systematically into parts so as to make the information to be expressed on the drawing corresponding to the manufacturing process and to avoid the duplication of information.
- General drawing ... Framing plane, marking drawing, framing elevation
- Assembly drawing, general assembly drawing, partial assembly drawing
- Single piece drawing
- Standard drawing ... Bolt joint standard drawing, welding standard drawing

In this system, the expression method of shop drawing was simplified and the drawing scheme was systematized. Simultaneously with this, files in the data base were made structural, thus finding the possibility of automatic preparation of shop drawings. This idea is an important factor in application of shop drawings and for taking measures againt the changing operations as may sometimes occur in production of steel structures.

(2) Production processing and production information

The data registered in the files relating to drawing processing are automatically subjected to member processing and then registered in the master file. Production processing is to output the contents of this master file as production

information.

The production information includes:
- Material list, material arrangement program
- Template
- Butting drawing, template drawing for drilling
- NC tape (drilling, cutting, marking)

Production processing includes:
- Processing for addition of fabrication data
- Material processing (sorting, nesting)
- Butting processing
- NC processing

Since the production information is outputted from the same data as have been checked at the stage of shop drawing, various stages of conventional manual operations can be unified and integraged. The effect of this system as a total system can be realized just by this production processing.

4. POSTFACE

The system as has been described above can realize the following items through the utilization of digital computer for preparation, control and application of all kinds of information in production of steel structures including the shop drawings and by introduction of automatic labor-saving machines such as NC machine tools.
- Unification or integration of production processes at various stages
- Mechanization of fabrication
- Continuity of production
- Higher standardization of operations

This system will be a pioneer in promoting the systematization in the industry of multikind and small quantity production type.